AIR FORCE
PROPOSAL PREPARATION INSTRUCTIONS

The responsibility for the implementation and management of the Air Force STTR Program is with the Air Force Research Lab, Wright-Patterson Air Force Base, Ohio. The Air Force STTR Program Manager is Steve Guilfoos, (800) 222-0336. All Phase I and Phase II STTR proposals **MUST** be submitted to the following administrative organization.

Air Force Office of Scientific Research
AFOSR/NI
4040 N. Fairfax Dr., Ste 500
Arlington VA 22203-1613
Attn: Dr. Victoria Franques
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The Pre-Solicitation Announcement (PSA), listing the full descriptions of the topics and the author of each, is issued electronically after being announced in the Commerce Business Daily. Contact AFOSR directly for information on future PSAs. Open discussions concerning technical questions pertaining to the topics can be held with topic authors (as listed in the PSA) until the solicitation formally opens. Once the solicitation opens the only way to ask pertinent technical questions about a topic with the topic author is through the DTIC SBIR Interactive Technical Information System (SITIS). For a full description of this system and the other technical information assistance available from DTIC, please refer to section 1.5c of this solicitation.

Unless otherwise stated in the topic, Phase I will show the concept feasibility and Phase II will produce a prototype or at least show a proof-of-principle.

Phase I period of performance is typically 1 year not to exceed $100,000.

Phase II period of performance is typically 2 years not to exceed $500,000. The solicitation closing dates and times are firm.

Air Force Fast Track
Detailed instructions on the Air Force Fast Track and Phase II proposals will be given out by the awarding Air Force directorate along with the Phase I contracts. The Air Force encourages businesses to consider Fast Track application when they can attract outside funding and the technology is mature enough to be ready for application following successful completion of the Phase II contract. Further information on the STTR Fast Track can be found in Section 4.5 of this solicitation.

Commercial Potential Evidence
An offeror needs to document their Phase I or II proposal's commercial potential as follows: 1) the small business concern's record of commercializing STTR or other research, particularly as reflected in its Company Commercialization Report http://www.dodsbir.net/submission; 2) the existence of second phase funding commitments from private sector or non-SBIR funding sources; 3) the existence of third phase follow-on commitments for the subject of the research and 4) the presence of other indicators of commercial potential of the idea, including the small business' commercialization strategy.

Submission of Final Reports
All final reports will be submitted to the sponsoring agency. Companies **will not** submit final reports directly to DTIC.

Proposal Submission Instructions

Your proposal will be accepted if you meet all of the following criteria. Failure to meet any one of the criteria will result in your proposal being rejected.

1. **All firms submitting STTR proposals to the Air Force must do so through the DoD SBIR/STTR Submission web site.** You must use the electronic format described in the Electronic Submission described below.

2. A copy of the Company Commercialization Report (formerly Appendix E) with summary page must be submitted with all proposals (See Section 3.4n of the solicitation). Even if you have no Phase I or Phase II awards, you must submit a Company Commercialization Report. Your proposal will not be penalized in the evaluation process if your company never had any STTR Phase I's or II's in the past**.** **The electronic submitted proposal and a hard copy** of the proposal must be received on or before the solicitation deadline unless it was sent by U.S. Postal Service Express Mail Next Day Service—Post Office to Addressee, not later than 5:00 p.m. at the place of mailing two working days prior to the date specified for receipt of proposals. The term "working days" excludes weekends and U.S. Federal holidays.

The Air Force will not accept late proposals, or incomplete proposals. If you have any questions or problems with
submission of your proposal allow yourself enough time to contact the Air Force and get an answer to your question.
Submit the electronic proposal early, as computer traffic increases, computer speed slows down. **Do not wait until**
The last minute. The Air Force will not be responsible for late proposals caused by computer systems or servers
being "down" or inaccessible. The Air Force will not be held responsible for late delivery of proposals, be advised
that an Overnight delivery may not reach the appropriate desk within one day.

Electronic Submission of Proposal

All firms submitting SBIR or STTR proposals to the DoD must do so through the DoD SBIR/STTR Submission web site, http://www.dodsbir.net/submission. This web site allows you to perform all of the steps necessary to submit a proposal including preparing a proposal cover sheet, creating a cost proposal, uploading your technical proposal and completing a company commercialization report. This site allows your company to come in any time (prior to the closing of the solicitation) to edit or print out your proposals. The Air Force will not accept any forms from past solicitation books or any electronic download version except those from the DoD SBIR/STTR Submission Website as valid proposal submission forms. Detailed instructions can be found by selecting the Help button on this site once you have registered. If you have any questions or problems with the electronic submission contact the DoD SBIR Helpdesk at 866-SBIRHLP (724-7457).

If you have never visited the site before, you must first register your firm and create a password for access (Have your Tax ID handy). Once registered, from the Main Menu:

Select "Prepare/Edit Phase I Cover Sheets" –

1. **Prepare and Print a Cover Sheet.** Add a cover sheet for each proposal you plan to submit. Once you have entered all the necessary cover sheet data and clicked the Save button, the proposal grid will show the cover sheet you have just created. You may edit the cover sheet at any time prior to the close of the solicitation. Click on the print icon to the right of the proposal number to display a print version of the cover sheet, and using your browser's print

function, send it to your printer. Sign and date the cover sheet and attach as pages 1 and 2 of your hard copy proposal submission.

2. **Prepare and Print a Cost Proposal.** Either use the on-line proposal form by clicking on the dollar sign icon, or prepare the cost proposal as the last section of your technical proposal file. If you use the on-line form, click on the printer icon to display a print version of the cost proposal, and using your browser's print function, send it to your printer. Sign and date the cost proposal and attach to your technical proposal for the hard copy proposal submission.

3. **Prepare and Upload a Technical Proposal.** Using a word processor, prepare a technical proposal following the instructions and requirements outlined in the solicitation. When you are ready to submit your proposal, click the on-line icon to begin the upload process. You are responsible for virus checking your technical proposal file prior to upload. Any files received with viruses will be deleted immediately. Technical proposal files must be in one of the following formats: Text, Rich Text Format (RTF), MS Word, WordPerfect, or Adobe Acrobat (PDF). Uploaded files will be converted to PDF format within an hour after the upload process is complete. You are required to check that your technical proposal was received and converted properly. Click on the check proposal icon to review the technical proposal.

Select "Prepare/Edit a Company Commercialization Report" –

4. **Prepare and Print a Company Commercialization Report.** Add and/or update sales and investment information on all prior Phase II awards won by your firm. Then reprint the Company Commercialization Report through your browser's print function. Even if you don't have any Phase II awards, you must print the Company Commercialization Report. Sign and attach at the very end of your hard copy proposal submission.

Once steps 1 through 4 are done, the electronic submission process is complete. One hard copy must also be mailed in. It must be exactly the same as the electronic submission. Assemble the hardy copy in this order: a) signed cover sheets, b) technical proposal, c) signed cost proposal, and d) signed company commercialization report. Mail one copy to the address specified in the Component's instructions.

TOPIC NUMBER	ACTIVITY/MAILING ADDRESS	CONTRACTING AUTHORITY
	(Name and number for mailing proposals and for administrative questions)	(For contract questions only)
AF02T001 thru AF02T002 AF02T005 thru AF02T017	Air Force Office of Scientific Research AFOSR/NI 4040 N. Fairfax Dr., Ste 500 Arlington VA 22203-1613 (Victoria Franques, (703) 696-7313)	Richard Pihl (703) 696-9728

FY02 STTR Topic Index

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AIR FORCE STTR FY 2002 TOPIC DESCRIPTIONS

AF02T001 TITLE: Integrated Sensing and Detection with Geo-Location

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Objective is to support precision weapons deployment through more accurate and flexible automated target recognition and identification.

DESCRIPTION: Object detection, recognition and geo-location are effected by various sensing modalities, including passive and active emanations, pressure waves (sound), variation in chemical concentration, and electromagnetic radiation. Originally the algorithms for sensor exploitation were physically and conceptually separate from the sensing mechanism. Subsequently, a large part of the necessary mathematical software was made to reside in a "smart sensing" receptor-processor. Improved technology now presents itself where highly parallel computations for target detection, identification and geo-location could take place within the sensing matrix itself. Further success in this area would lead to more compact and conformal sensing packages capable of delivering organized and useful targeting data instantly to the Warfighter. Parts for implementation that will bear on progress in integrated sensing include optical components, hyper-spectrally sensitive materials (HSS), photonic, electronic and hybrid circuitry, nano-mechanical devices and chemical computers. Results of received input are used in this integrated system, not only for ultimate object discrimination and geo-location, but also to activate complementary active and passive sensing modalities. A whole suite of established and innovative image-forming software can be proposed for integration in such a seamless, smart sensing configuration. These algorithms include shock-capturing, classical de-convolution, super-resolution, multi-scale and edge detection methods, multi-modal fusion, geometric processing of polarimetric SAR, brightness/motion detection, electric-magnetic vector analysis and many others. For example, thermally sensitive smart materials could initiate range-finding laser radar when a designated signature profile is verified. Research will be conducted to see how mathematical theories of adaptive sampling, scene cross-registration, jitter/rotation compensation and sensor placement can be put into effect directly on the sensing substrate. If this is so, the comprehensive system will be able to employ an intrinsic computational capability to control and direct its sensing assets. The research performer should develop familiarity with applications and methodologies of importance to the Air Force, and by the end of Phase I as is a convincing road map or plan for the eventual technical insertion of the results of the project.

PHASE I: Extend the state-of-the-art in one or more critical areas of integrating sensing with computation and control, with published foundational achievements. These innovations could be in the topical areas listed above or other basic technologies. Through simulations and analysis of simplified scenarios that still contain essential elements of the real-world challenge, instill high confidence in eventual feasibility of the methods.

PHASE II: Develop a realistic integrated framework based on the methodologies from Phase I. Extend the framework and attendant algorithms to deal with several of the exigencies and disruptions that arise in a combat environment that make multi-mode sensing necessary. Document a plan showing how these algorithms increasingly can be integrated into actual sensing hardware and materials, with a gain, not a loss, in versatility and reliability. This can best be accomplished through a broadly-based prototype system that exhibits superior sensing response and data utilization under a wide range of ambient parameters.

PHASE III DUAL USE APPLICATIONS: A wide variety of sensing devices is part and parcel of consumer products as well as manufacturing systems. The miniaturization achieved through DoD research in electronic and mechanical systems will lead to greater power efficiency and make flexible remote control in the industrial environment easier to achieve. These areas have been predicted to stimulate revenues in the billions of dollars within the next ten years.

REFERENCES:
1. "Special Purpose Hardware for Discrete Fourier Transform Implementation", Michael Conner and Richard Tolimieri, Parallel Computing 20 (Elsevier, Amsterdam).
2. "Distributed Detection and Data Fusion", P.K. Varshney, Springer-Verlag New York, 1997.
3. "Non-Linear Filtering and Sensor Management", K. Kastella, ERIM Technical Report 463500-1-F, Ann Arbor 1996.

KEYWORDS: Target Detection, Geo-location, Multi-spectral Imaging, Smart Sensing

AF02T002 TITLE: Fast, Robust Real-Time Trajectory Generation for Autonomous and Semi-Autonomous Nonlinear Flight Systems

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop, implement, and demonstrate algorithms for real-time trajectory generation of autonomous nonlinear flight systems. The algorithms must be capable of dealing with complex nonlinear vehicle dynamics, actuator and system constraints, as well as fixed and pop-up threats.

DESCRIPTION: Current and future unmanned aerial vehicle (UAV) and smart munition systems require sophisticated online path generation that can account for unknown terrain obstructions and moving threats such as radar, jammers, and other aircraft [2,3,4]. Other objectives would include minimizing vehicle profile on enemy radar and optimizing communication antenna gain when determining a feasible path and vehicle orientation. Frequently, these systems may be required to perform optimally in the nonlinear region of the flight envelope. Furthermore, these nonlinear algorithms must be computationally efficient so that the desired trajectory can be generated in real time during a mission, [1]. Laboratory demonstrations have shown that advances in computational algorithms have brought such real-time trajectory generation within reach [2,5]. The purpose of this program is to build on those advances and implement such algorithms in a flight hardware environment.

PHASE I: Develop proof of concept algorithms and determine system requirements for implementation in flight vehicles, including computational platform and redundancy/failure management.

PHASE II: Implement the algorithms on a flight platform and complete hardware-in-the-loop testing. Include sample tasks requiring dynamics path planning capability.

PHASE III DUAL USE APPLICATIONS: Perform a physical demonstration of the algorithms tested in Phase II on a representative air vehicle platform. Successful development of advanced trajectory-generation algorithms could bring benefits to a variety of vehicle systems for air, land, sea, and space applications. Optimization-based control techniques achieved with these fast algorithms can be applied to various control systems in need of dynamic reconfiguration based on real-time changes in system condition, mission, or environment. Examples of such applications involving the proposed trajectory generation algorithms include mid-air collision avoidance and unmanned aerial vehicles in border and police enforcement. The latter contributes to the mission of homeland security in surveillance around airports and other high-security areas, e.g., high profile buildings. Further extension of these algorithms can be applied to the control of multiple unmanned systems such as battlefield sensor vehicles.

REFERENCES:

1. S. K. Agrawal and N. Faiz, “A New Efficient Method for Optimization of a Class of Nonlinear Systems Without Lagrange Multipliers”, Journal of Optimization Theory and Applications, 97, No. 1, 1998.
2. E. Frazzoli, M. A. Dahleh, E. Feron, “Real-Time Motion Planning for Autonomous Vehicles,” Allerton Conference on Communication, Control and Computing, Monticello, IL, 2000.
3. D. Godbole, T. Samad, and V. Gopal, “Active Multi-model Control for Dynamic Maneuver Optimization of Unmanned Air Vehicles,” Proceedings of the IEEE International Conference on Robotics and Automation, 2000.
4. J. Hauser, and A. Jadbabaie, “Aggressive Maneuvering of a Thrust Vectored Flying Wing: A Receding Horizon Approach,” IEEE Conference on Decision and Control, 2000.
5. M. B. Milam, K. Mushambi, and R. M. Murray, “A Computational Approach to Real-Time Trajectory Generation for Constrained Mechanical systems,” IEEE Conference on Decision and Control, 2000.

KEYWORDS: Autonomous/Semi-autonomous Flight Systems, Real-time Trajectory Generation, Navigation and Guidance, Autonomous Path Planning/Replanning

AF02T005 TITLE: Controlled Nucleation and Growth in Semiconductor Epitaxy

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: Use externally applied fields to control the semiconductor epitaxy growth front

DESCRIPTION: Native defects in semiconductors can dominate their performance characteristics. Non-ideal growth conditions result in native defects such as faults in the atomic stacking arrangement, and antisite defects in compound semiconductors. Growth occurs when an atom hits the surface and moves to a step site where the total bond energy is much greater than the bond energy of the flat surface. Growth at a temperature that is too low doesn’t provide the adatom with enough surface mobility to find a step, potentially resulting is stacking faults. The surface mobility is controlled by the residual bond energy after surface reconstruction. It may be possible to apply an external field to change the effective adatom bond energy. For example, an external field can be applied to extend the evanescent waves from the semiconductor surface to change the effective bond energy, or apply an external field resonant with the adatom, but with enough jitter or controlled phase shift to enhance the surface mobility. Higher surface mobility of adatoms will make a wider range of growth conditions available as well as improving semiconductor crystalline perfection. Lower growth temperatures are desirable to control interdiffusion at heterojunctions.

PHASE I: Identify an approach that alters the bond energy at the growth front so that positive control can be exercised over the surface mobility of the adatom. Model the surface kinetics to determine the appropriate electromagnetic field strength, orientation, frequency, etc. Select a simple growth system and complete an initial demonstration. Characterize the material to quantify the benefits of the added external control.

PHASE II: Continue development of the technology pursued in Phase I, and demonstrate successive improvements. Investigate the range of control that can be applied effectively to the growing epitaxial surface. Quantify the relationship between external controls and material quality.

PHASE III DUAL USE APPLICATIONS: Additional controls on the epitaxial process, other than temperature and flux ratios, for example, will enable higher quality films with reduced native defect concentration. Higher quality films will result in better efficiency in a variety of devices. Without carrier loss via the recombination centers that are associated with defects, lasers will have lower threshold currents. Similarly, detectors will have lower dark currents, and transistors will have higher gain.

REFERENCES:
1. P. M. DeLuca, K. C. Ruthe, S. A. Barnett, “Glancing-angle ion enhanced surface diffusion on GaAs(001) during molecular beam epitaxy,” Physical Review Letters; vol.86, no.2, p.260-3 (8 Jan. 2001).
2. Zheng, L.X.; Xie, M.H.; Xu, S.J.; Cheung, S.H.; Tong, S.Y., “Current-induced migration of surface adatoms during GaN growth by molecular beam epitaxy,” Journal of Crystal Growth; vol.227-228, p.376-80 (July 2001).
3. Tatsuoka, Y.; Uemura, M.; Kitada, T.; Shimomura, S.; Hiyamizu, S., “Substrate temperature dependence of surface migration of As atoms during molecular beam epitaxy of GaAsP on a (411)A GaAs substrate,” Journal of Crystal Growth; vol.227-228, p.266-70 (July 2001).
4. Dumont, H.; Monteil, Y.; Bouix, J., “Energy barrier for the growth transition step-flow/step-bunching during epitaxy of InP/InP,” Applied Surface Science; vol.161, no.1-2, p.286-90 (July 2000).
5. Dvurechenskii, V.A.; Zinovyev, V.A.; Markov, V.A.; Kudryavtsev, V.A., “Surface reconstruction induced by a pulsed low-energy ion beam during Si(111) molecular beam epitaxy,” Surface Science; vol.425, no.2-3, p.185-94 (20 April 1999)

KEYWORDS: epitaxy, semiconductor, crystal growth

AF02T006 TITLE: Isomeric Targets for High-Energy Density Applications

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Identify sources and production methods for isomeric materials. Build and characterize high-energy density targets containing isomeric materials for experiments and potential applications.

DESCRIPTION: Extremely high energy densities can be found in isomeric materials in which long-lived excited nuclear states may store up to 1.2 GigaJoules/gram for up to decades. Spontaneous decay of these special nuclear states occurs typically by gamma decay only, leading to no direct residual radioactivity. Some recent experiments have suggested that a triggered energy release in the form of gamma rays may be produced, or driven, by incident x rays of much lower energy. This process could provide a means of controlling the energy release as a form of nuclear battery. More experiments are needed to completely resolve the physical situation for the first isomeric material of interest, Hafnium-178m2. New targets must be designed, built and characterized to support these experiments. In addition, other isomer materials may be of interest, and the possibility of constructing experimental targets with those isotopes must be investigated.

Existing 178m2Hf stocks are limited and are contaminated with other hafnium isomers and a high percentage of ground state hafnium. Future research and application developments depend on the creation and purification of new stocks of various isomers.

The purpose of this program is to identify sources of isomer material and develop isomeric targets, first of Hf-178m2 and then of other promising isotopes, for further basic physics experiments. These experiments may be conducted at government-funded academic institutions, government facilities or one of the National Laboratories in addition to the offeror’s facilities, if suitable. Later steps will include the design and construction of targets more suitable to pre-application tests.

The extremely great promise of isomeric materials for many applications ranging from medicine to satellite power emphasizes the importance of accurate basic experimental knowledge. To acquire such information it is necessary to extensively explore target composition and design to optimize test sensitivity. Models of the triggering process, if upheld by further experiments, will then be required to assess the feasibility of potential applications.

PHASE I: Investigate isomers that show promise for commercial or government applications of triggered radioactive decay. Identify experiments necessary to further the development of applications utilizing these isomers. Acquire raw isomeric material from established reactor or accelerator facilities or other sources. Design and fabricate target source holders that incorporate small quantities of Hf-178m2 (under 20 micro-Curies for test purposes) and other promising isomers which may be identified by the offeror as available to support these experiments.

PHASE II: Continue the analysis of promising isomers to identify the best candidates. Identify sources of isomer materials. Identify methods to separate and purify existing isomer stocks. Design experiments to characterize isomer behaviors and determine parameters necessary to develop successful applications. Refine the target source holder designs created in Phase I to accommodate these new experiments.

PHASE III DUAL USE APPLICATIONS: Develop production plans to satisfy the inventory needs of isomer researchers and applications developers for the next decade. Design and fabricate an isomer target that can serve as the core of a net-positive energy release demonstration system. A successful demonstration would lead to applications for defense, space propulsion, energy storage, medicine, and numerous other areas.

REFERENCES:
1. Collins, C., Davanloo, F., Iosif, M., Dussart, R., Hicks, J., Karamian, S., Ur, C., Popescu, I., Kirishuk, V., Carroll, J., Roberts, H., McDaniel, P., Crist, C., "Accelerated Emission of Gamma Rays from the 31-yr Isomer of 178Hf Induced by X-Ray Irradiation," Physical Review Letters, 82:4, 695 (25 January 1999).
2. Roberts, H., "The importance of stimulated gamma release from isomers," Hyperfine Interactions 107 (1997).
3. Carroll, J. J., Karamian, S. A., Rivlin, L. A., Zadernovsky, A. A., "X-Ray Driven Gamma Emission," Hyperfine Interact. (in press 2002).

KEYWORDS: High energy density materials, Isomers, Target preparation and characterization

AF02T007 TITLE: Atomic-Layer Controlled Coatings on Particles

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop methods to coat particles with atomic layer controlled films. The ability to control the thickness and conformality of films on a variety of particles including metal, oxide and polymeric materials will also be demonstrated.

DESCRIPTION: Particles are used in many applications because of their desirable bulk properties. Unfortunately, the surface of the particle is often not ideal for the particular application. The ability to deposit well-controlled coatings on particles would offer a wide range of technological opportunities based on changes to both the physical and chemical properties of the particles. Atomic layer controlled coatings on particles, for example, would allow particles to retain their bulk properties but yield more desirable surface properties. These ultrathin coatings could act to activate, passivate or functionalize the particle to achieve both desirable bulk and surface properties. One example is useful for illustration. AlN particles have high thermal conductivity and are added to composites for thermal management applications. One difficulty is that H_2O can corrode the AlN particles and generate NH_3. Ultrathin coatings on AlN particles could protect the AlN particle from H_2O corrosion without compromising its high thermal conductivity. Novel methods to deposit atomic layer controlled coatings on particles are desired that can be applied to model systems and systems of both military and commercial uses.

PHASE I: Identify novel methods for depositing atomic layer controlled coatings on particles. Demonstrate the viability of these new methods on a model system. Verify the ability of the method to deposit an atomic layer controlled and conformal coating.

PHASE II: Demonstrate the ability of the new methods for atomic layer controlled growth to deposit on macroscopic quantities of particles. In conjunction with a commercial or military application, verify the usefulness of the atomic layer controlled film on the particle. The expectation is that by the end of Phase II that this new method would be ready for implementation or commercialization.

PHASE III DUAL USE APPLICATIONS: These new methods to deposit atomic layer controlled films on particles are expected to have a variety of commercial and military applications. Specific applications may include protecting and activating coatings on thermal management materials, insulating and protecting coatings on metal particles and diffusion barriers on polymer particles for food and medical packaging. This new methodology can leverage existing particle technology and yield new particles that can not be produced by other means. The value added by the atomic layer controlled coating is expected to be great at little additional cost.

REFERENCES:
(1) See “National Nanotechnology Initiative: Leading to the Next Industrial Revolution,” A Report by the Interagency Working Group on Nanoscience, Engineering and Technology Committee on Technology, National Science and Technology Council, February 2000, Washington, D.C.
(2) “Nanotechnology: Shaping the World Atom by Atom,” National Science and Technology Council, September 1999, Washington, D.C.

KEYWORDS: Modified particles, functional films, protective coatings, nanostructures and nanocomposites.

AF02T008 TITLE: Intermediate Temperature Carbon/Carbon Structures

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: This STTR topic seeks research proposals on carbon/carbon structures designed for long term applications at 700-1200°F and with at least 2X improvement in compressive and tensile strength over current carbon/carbon composites in this temperature range. The goal is to provide a lightweight structural material suitable to replace titanium components in applications in the stated temperature range.

DESCRIPTION: Carbon/carbon structures are traditionally designed and optimized for high temperature applications. They have very high temperature capability under inert atmospheric conditions but suffer from thermoxidative instability above ~700°F without oxidation protection and poor mechanical strength. Oxidation protection technologies developed to enable use above ~1800°F in thermoxidative environments have had limited success. Current theoretical thermal limit for polymeric matrix carbon fiber reinforced composites is about 700°F due to thermal decomposition/degradation and poor thermal conductivity. Carbon/carbon structures would be an ideal materials technology to extend organic-based materials beyond the 700°F limit if the mechanical strength can be improved and maintained by preventing oxidation of the composite. The approach is to utilize the high temperature resistance and high thermal conductivity of C/C to target at a temperature range where oxidation protection schemes for C/C are feasible, but is beyond the current capability of PMC’s. Targeting this temperature range may also allow optimization of the materials to improve its mechanical strength. This topic seeks innovative material design, processing and oxidation protection approaches for developing low-cost, high strength carbon/carbon structures and multi-functional components with long-term (thousands of hours) 700-1200°F use capability.

PHASE I: Define potential applications and material requirement goals. Propose and demonstrate innovative material design, processing and oxidation protection approaches and/or processing concepts for developing carbon/carbon structures with 700-1200°F use capability and that maintain their structural properties for 1000 hours.

PHASE II: Develop the proposed material technology and conduct tests to validate the appropriateness of the proposed chemical approaches and/or processing concepts to provide carbon/carbon structures with long term 700-1200°F use capability and maintain their structural properties for 1000 hours.

PHASE III DUAL USE APPLICATIONS: Lightweight high temperature structural materials for civil transport and engine components, exhaust washed structure, thermal management (environmental control and power systems), automotive and specialty vehicle applications (race cars, high speed trains, etc.).

REFERENCES:
D. L. Schmidt, “Carbon-carbon Composites (CCC) – A historical perspective”, US Air Force Research Laboratory Technical Report WL-TR-96-4107. Sept., 1996.

KEYWORDS: Carbon/Carbon And High Temperature Structural Materials

AF02T009 TITLE: Automated Acoustic Monitoring of Birdstrike Hazards

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop techniques to identify and evaluate birdstrike hazards through acoustical monitoring and automated acoustical analysis.

DESCRIPTION: Collisions between birds and aircraft are a continuing hazard. Damage to and destruction of aircraft, both military and civilian, and the human fatalities that often follow, could be minimized with bird-avoidance technology that provides real-time reporting of bird population/movement data. The birdstrike hazard is increasing in some geographic regions, especially those that host increasing populations of resident or migrating birds. Larger species, such as geese, turkey vultures, pelicans, cormorants, and red-tailed hawks present the main hazard, but collisions with smaller, flocking birds can be just as significant.

Acoustical monitoring can provide real-time information about migrating and resident bird populations, and could be integrated with other sensor data such as radar. Automated analysis of acoustical data is essential for three reasons. (1) The volume of acoustical data derived from even a small number of microphones can be too large for human listeners or human analysts to inspect. (2) Algorithms are needed to estimate parameters such as airspeed, trajectory, altitude, and airborne population density. (3) An automated analysis can provide simultaneous information to widely-distributed monitors, such as pilots, air-traffic controllers, flight-planners, students, ornithologists, etc., e.g. via the internet.

A primary research task is to develop and validate signal-processing methods that reliably identify bird species from acoustic (e.g., microphone-based) data. Species identification is critical to establish the weight-dependent aspect of a collision hazard. The acoustic signal inputs in most cases will be bird vocalizations, although other sound signatures are not ruled out. Algorithms for the analysis of these acoustical images must operate in a low signal-to-noise environment and against backgrounds of significant transient interference. Robust methods are therefore required. A second challenge is to significantly, and inexpensively extend the reach of ground-based acoustic monitoring devices beyond an altitude range of hundreds of meters.

PHASE I: Develop and validate signal processing to reliably and automatically classify species of birds in flight, based upon real-time, ground-based acoustical data. Develop prototype acoustic sensors to significantly extend the effective range (altitude) at which acoustic sensing and classification can be effective.

PHASE II: Improve and refine the techniques developed in Phase I. Refinements may include automated estimates of flight path, altitude, trajectory, and flock density for each identified species. Develop prototype, low-cost acoustic monitoring stations with commercial potential. Develop platform-independent software to permit integration of acoustical monitoring data from multiple, widely-distributed monitoring stations and to provide real-time access to bird flight patterns. Demonstrate to the Air Force Flight Safety Center how the products of this research and development effort can be used to improve the Air Force bird avoidance program.

PHASE III DUAL USE APPLICATIONS: Improved monitoring of migratory and non-migratory birds in flight will inform both civilian and military air traffic planning and operations to reduce the birdstrike hazard. Acoustic monitoring stations, if produced in quantity, can be inexpensive nodes in an expanding, computer-linked network for bird monitoring and avoidance. Such a monitoring system will be needed when GPS-based free-flight systems are introduced for air traffic control.

REFERENCES:
1. Evans, W. R. & Rosenberg, K.V. (2000). Acoustic Monitoring of Night-Migrating Birds: A Progress Report. In R. Bonney, et al., (Eds) Strategies for Bird Conservation: Proceedings of the 3rd Partners in Flight Workshop. Cape May, NJ, Oct. 1-5, 1995. Available on website: http://birds.cornell.edu
2. Wildlife Strikes to Civil Aircraft in the United States. FAA report. Available on website: http://www.faa.gov/arp/pdf/bash9099.pdf
3. Mills, H. (2000) Geographically distributed acoustical monitoring of migrating birds. J. Acoust. Soc. Am. 108(5), Part 2. P.2582 [Abstract].
4. Rosenthal, D.F. & Okuno, H.G., (Eds.). Computational Auditory Scene Analysis. Lawrence Erlbaum, 1998.
5. Bioacoustics: The International Journal of Animal Sound and its Recording.

KEYWORDS: Bioacoustics, Acoustic Sensing, Avian Hazard Analysis

AF02T010 TITLE: Geopolymers for Structural Ceramic Applications

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: To design, synthesize and characterize ceramic matrix composites derived from geopolymers (polysilicates) for application in structural ceramic components. The proposed research seeks to explore new concepts for designing new geopolymeric ceramics through the understanding of the fundamental reaction mechanisms and to provide new insight into the control of the structure and ultimately the high temperature properties of this unique class of materials.

DESCRIPTION: Brittleness and unreliability in ceramics remain challenging problems; however, attempts to impart "graceful failure" have been partially successful with the use of ceramic matrix composites (CMCs). The selection and integration of the appropriate fiber, fiber coating and matrix are vital to the ultimate toughness of the composite. In spite of considerable research, there is still a need for a tough, flaw tolerant, oxide composite that is relatively dense and can perform in a high temperature, oxidizing environment. A novel approach to developing an oxide CMC that has these qualities may be found in the exploration of geopolymers. Geopolymers are a class of amorphous to semi-crystalline three dimensional alumino-silicate materials originally reported in 1978 by Joseph Davidovits and recently reviewed in 2000 by J.S.J. Van Deventer. They are similar to zeolites in terms of chemical composition but are otherwise very different because they do not possess crystallinity and have extremely low porosity. Geopolymers can be synthesized at ambient temperature from almost any alumino-silicate (e.g. sillimanite (Al_2SiO_5), celsian ($BaAl_2Si_2O_8$), or spodumene ($LiAlSi_2O_6$)) and have useful properties such as compressive strengths up to 19MPa, Mohs hardness of 4-7, thermal stability up to 1300-1400 $^\circ$C, and low permeability values. Furthermore, by changing the Si /Al ratio, it is possible to produce products with a broad range of physical and mechanical properties. The applications of these materials have been severely constrained by a lack of understanding of the reaction mechanisms including the role of the formation of a highly reactive intermediate gel phase during the polymerization on the mechanical properties of the final geopolymer. The application of geopolymers to CMCs is a logical next step in the exploration of new oxide composite systems.

PHASE I: Demonstration of the synthesis of ceramic composite material utilizing a geopolymeric process. Develop approach for understanding the reaction mechanisms that control the formation of the three-dimensional alumina-silicate network and the resultant microstructure. Research may focus on either the fiber, fiber coating or matrix phase of the geopolymer but should attempt to correlate experimental results with established CMC models that enable the prediction of mechanical properties based on microstructure observations.

PHASE II: Produce and demonstrate a prototype of a geopolymeric CMC and provide a materials property database.

PHASE III DUAL USE APPLICATIONS: Cost effective routes to ceramic matrix composites are extremely important to the ultimate viability of ceramics in military and commercial airframe and engine components. The need to control cost while simultaneously improving performance has been a major driver in the exploration of ceramic composites across a wide spectrum of commercial markets including, power generation, sensors, biomedical devices, and protective barrier coatings.

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KEYWORDS: Geopolymer, structural ceramic, processing

AF02T011 TITLE: Stabilization of Thin Membranes Using Smart Materials

TECHNOLOGY AREAS: Materials / Processes

OBJECTIVE: Develop/characterize actuators for control of thin film membranes to optical requirements.

DESCRIPTION: Thin membranes, such as those envisioned for future membrane mirrors, offer the potential to dramatically reduce the mass and cost of future optical space systems. To achieve optical quality in a membrane mirror, tremendous precision is required. Often only a few tens of nano-meters of error are allowed over a surface several meters in diameter. In addition, packaging may be required such that the membrane must be folded or rolled and then later deployed. Recently, smart materials such as thin-film shape memory alloys, piezo-electric materials, and various active polymers have emerged as a possible solution to this problem, but they have not been investigated in detail. This topic seeks innovative smart-material based approaches for actuation of membrane structures to achieve optical quality surfaces once deployed. Typical research issues include: (1) characterization of various smart materials for thin film shape control, (2) development of material performance models for design, (3) development of shape control schemes, (4) fabrication and integration of sensors and actuators, and (5) design and fabrication of thin films with sensors and actuators for optical quality surface control.

PHASE I: Select and characterize several candidate smart materials for their multifunctional performance including micro-strain and micro-yield properties. Develop constitutive models required for actual device design. Examine the performance and applicability of these materials in membrane optical systems.

PHASE II: Demonstrate precision shape control of thin film membranes for optical performance using a down-selected set of materials. Include optically based sensing techniques as part of this effort.

PHASE III DUAL USE APPLICATIONS: Thin-film materials have several military and non-military applications. Large aperture systems such as Space Based Laser have low surface accuracy tolerance requirements and low area density requirements that make thin-film materials attractive. Surveillance missions have similar requirements. Many applications are possible in commercial satellites.

REFERENCES:

KEYWORDS: Membrane mirror, smart materials, shape control, optical performance

AF02T012 TITLE: Mitigation of Aero-Optic Distortions by Active Flow Control

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Demonstrate an integrated actuation system that can reduce aero-optic distortions by control of large-scale shear layer structures and manipulation of the turbulence spectrum in a compressible flow.

DESCRIPTION: An important measure of performance for a tactical laser system is the intensity of the beam on a target. The performance of these systems is degraded substantially by index of refraction variations in a boundary layer or shear layer. Adaptive-optics corrections may correct for phase front distortions to the beam caused by turbulence, but the spatial and temporal frequencies associated with compressible shear layers occurring in flight poses a formidable challenge, requiring high frequency wavefront sensing, signal analysis, and correction.

Simulations have recently shown that unsteady optical distortions are caused mainly be the natural, large-scale vortical structures in the shear layer. If the temporal frequencies associated with these structures are too high to allow real-time sensing and correction, two alternatives may exist. First, the structures may be forced in order to regularize the flow and reduce the spatial and temporal requirements for wavefront sensing. Second, artificial excitation may be used to artificially alter the development of the shear layer, leading to a modified spectral profile of the turbulence. Recent research has suggested that forcing at appropriate frequencies—much higher than the frequencies associated with large scale motion, but much lower than the Kolmogorov viscous scale—may increase the turbulent dissipation rate and reduce the turbulent production, leading to a significant decrease in the energy in the large-scale structures shown to be most detrimental to the laser systems. Furthermore, these effects appear to persist into the transonic regime.

An actuation system designed to control large scales and manipulate the turbulence spectrum may provide systematic improvements to the performance of a tactical laser system. The actuation system must be designed for realistic flight Mach and Reynolds numbers, and realistic flight temporal and spatial scales. Furthermore, the effort should quantify the effect of forcing on compressible shear layers using appropriate computational and experimental techniques, develop proper means of scaling the results for Mach number and Reynolds number effects, analyze the impact of control on the distortion of a laser beam propagating through the shear layer, and demonstrate the system effects in an appropriate diagnostic facility. A physical demonstration of the complete system on a realistic system geometry at flight Mach numbers must be considered.

All aspects of the actuator design, development, implementation and system integration, including compactness, power requirements, integration requirements and ruggedness will be considered in the evaluation and should be addressed in the proposal. Simulation strategies and test plans to quantify system level impacts of the actuation for realistic geometries and Mach numbers, including experimental facilities, diagnostics required for beam measurements, simulation fidelity and scaling of results, will be considered in the evaluation and should be addressed in the proposal.

PHASE I: Assess candidate actuators and shear layer control methodologies for application to optical systems. Develop approach for modeling the turbulent flows, including the effects of actuation. Perform preliminary demonstration of actuation in a turbulent boundary layer or shear layer and quantify the effects of actuation on optical system performance. Identify all scaling issues for operational frequencies, compressibility effects, and system performance measurements. Develop a test and implementation plan for Phase II.

PHASE II: Continue development of the flow control devices and the system-integration of these devices for reducing the distortion of a laser beam propagating through the shear layer. Demonstrate the actuation system in an experimental simulation at realistic Mach numbers and Reynolds numbers and quantify the effect of the actuation on system performance.

PHASE III DUAL USE APPLICATIONS: Successful development of flow control to mitigate aero-optics effects may have important implications for optical data links with commercial aircraft. Such devices may also see broad application in other flow fields where the manipulation of the turbulent cascade is desirable, such as reacting flows, and cavity flow fields.

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KEYWORDS: Flow Control, Turbulence, Aero-optics, Actuators

AF02T013 TITLE: Biological Decontamination for Forward-Deployed Airbase Using Low Temperature Air Plasmas

TECHNOLOGY AREAS: Chemical/Biological Defense

OBJECTIVE: Innovative concepts are sought to exploit the recently discovered capability of atmospheric pressure plasmas to sterilize biologically contaminated surfaces. In particular, although the basic effectiveness of such plasmas in this role has been demonstrated, the underlying physical mechanisms that enable the rapid killing of bacteria and spores remain a subject for debate. The scientific goal of this effort will be to obtain hard data to identify and prioritize the responsible kill mechanisms so that air plasma-based decontamination equipment can become a reality.

DESCRIPTION: The decontamination of forward-deployed equipment and facilities that have been exposed to deadly biological warfare agents continues to be of utmost concern. Current techniques utilize high temperatures, strong chemicals, and/or ultraviolet radiation to sterilize contaminated items. All these approaches can require significant fractions of an hour to be effective over a limited amount of surface area. In addition, insulated chambers, toxic waste fluid, and personnel hazards are among the undesirable side effects of those techniques. In a combat situation, one prefers a self-contained system that is easy to use with no hazardous byproducts. Clearly, techniques that work in minutes rather than hours are also greatly preferred.

Over the past four years, it has been demonstrated in university and industrial laboratories that materials exposed to atmospheric pressure discharge plasmas can be sterilized of biological contaminants in timescales on the order of minutes. Such plasmas are simple to create, can be switched on-and-off, and produce gaseous byproducts that are relatively easy to locally control. However, fundamental questions remain to be answered regarding exactly HOW the bacteria and spores are killed so quickly. Among the candidate mechanisms at work are free radicals, ozone, and ultraviolet (UV) radiation. Carefully diagnosed experiments are now required to finally identify the primary mechanism(s). The results of such research would contribute to the future optimization of such technology with respect to power consumption and field-portability.

PHASE I: Perform a feasibility study to design a laboratory atmospheric plasma decontamination apparatus configured with detailed diagnostic equipment for identifying air plasma species, UV radiation dosimetry, local electric field strengths, etc. Write a research plan for evaluating the effectiveness of such a device for the rapid sterilization of biological contaminants.

PHASE II: Construct the laboratory test apparatus that was designed in Phase I and use it to test the concept of an atmospheric plasma biological decontamination system. Evaluate the effectiveness of this proof-of-principle system against non-toxic simulants of biological warfare agents that can be safely dealt with in a typical laboratory environment. Obtain data substantiating and prioritizing the alternative kill mechanisms that are present. Theoretically and empirically seek to determine the lowest power requirements for effective operation.

PHASE III DUAL USE APPLICATIONS: If the viability of such a new decontamination approach is proven, the awardee should proceed to the prototype construction phase. Such a device could revolutionize sterilization techniques throughout the entire civilian and military medical communities. The potential commercial market for safer, cooler, and more rapid sterilization devices is staggering. Sepsis is THE major post-operative cause of death in American hospitals.

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KEYWORDS: Biological Decontamination, Air Plasma, Sterilization

AF02T014 TITLE: Plasma and Photoionization Approaches for Combustion Initiation

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Formulate novel approaches for ignition and combustion enhancement for future chemical propulsion systems based on studies on the use of pre-ionization, enhanced dissociation by direct electron impact, and photo dissociation with the control of applied reduced electric fields (E/N) in nonequilibrium plasmas to augment ignition in the combustion of hydrocarbon fuels. E is the applied plasma electric field, and N is the gas density. This capability will be needed for hypersonic flight vehicles and high-altitude UAV’s and for environmental compliance for future aircraft.

DESCRIPTION: The performance and maneuverability of vehicles utilizing chemical propulsion systems depend on the successful ignition of the combustion event, on demand. Furthermore, on-board auxiliary power generation units for directed energy weapons also require reliable starting capability of turbo generators on demand. Ignition of a given fuel/oxidizer mixture depends on the sustained production of key radical species at the onset of combustion. In conventional propulsion systems utilizing spark ignition, the initiation of combustion hinges on a sufficient local concentration of radical species produced early after the spark discharge by direct electron-impact and photo dissociation processes. Combustion then is sustained at longer times by exothermic release of energy from specific elementary processes. Therefore, the local air-fuel ratio and local temperature at the point of ignition are of primary importance. The effects of the initial spark discharge on the production of radicals, dissociated fuel fragments, and chemi-ions on combustion usually have been ignored. However, it is clear from recent work [1-4] that chemi-ionization (and possibly vibrational excitation) processes dominant during the early stages of ignition and combustion are indicators of onset of ignition, extent of combustion, and local air-fuel ratio. The proposed research is expected to develop computational, experimental, and theoretical tools for a model pre-mixed CH_4/air system that will lead to a better understanding of ignition processes over a wide range of pressure and gas temperature. Another important aspect of the proposed research will be the use very high E/N pulsed plasma for the energy efficient generation of radicals, and fuel dissociation which can significantly alter ignition phenomena.   The ultimate objective of the research is the creation of novel ignition devices and approaches that will remove deficiencies found in current igniter designs.

PHASE I: Design a high E/N variable duration pulsed plasma ignition module to study ignition of hydrocarbon fuel/ oxidizer mixtures as a function of gas pressure, gas temperature, and flow velocity. Investigate the performance of a plasma igniter from the ignition delay measurements as a function of total input energy and fuel/ air flow conditions.

PHASE II: Develop measurement techniques to quantify the effect of nonequlibrium plasmas on the production of ignition kernels through direct and indirect electron impact produced reactants. Formulate design rules for a nonequilibrium plasma igniter for application in high altitude engine relight and also for a supersonic combustor.

Demonstrate ignition enhancements in a simulated combustion environment. Produce and test the performance of a prototype ignition device based on the results of the Phase I and Phase II studies.

PHASE III DUAL USE APPLICATIONS: Successful research will produce novel igniter concepts that can be used for aerospace and terrestrial propulsion systems and for power production. For example, in addition to aerospace applications, novel igniters would be attractive for diesel engines, including propulsion for Army tanks and trucks

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KEYWORDS: combustion ignition plasma photoionization propulsion

AF02T015 TITLE: Exploitation of Omnidirectional Reflectivity

TECHNOLOGY AREAS: Information Systems Technology

OBJECTIVE: Deliver a software package which is capable of predicting/simulating the propagation of electromagnetic (EM) waves in both planar and nonplanar dielectric media as well as predicting/simulating the performance of devices (waveguides, cavities, protective screens) fabricated from such media.

DESCRIPTION: It has recently been shown (see Ref 1) that a reflector which reflects electromagnetic radiation from all incoming angles and over a broad range of frequencies (the conventional metallic mirror does this) but exhibits virtually no absorption losses (the conventional metallic mirror doesn't do this) can be fabricated from a layering of suitable dielectric planar layers. This reflector operated in the 10-15 micrometer wavelength regime. It would be of great utility to the Air Force if reflectors which operate in other wavelength regimes (for example but not limited to microwave (MW) and millimeter (MMW) wave frequencies) and other nonplanar geometries (cylindrical or cavity) could be fabricated. From a Phase III perspective such devices would provide the Air Force with ultra-low loss waveguides and laser cavities as well as a conformal laser hardening capacity and even advanced MMW/MW circuitry for better mode control in broadband/highgain/highpower amplifiers for High Resolution Radar systems and directed energy applications.

PHASE I: Perform an analytical/numerical study of electromagnetic wave propagation in planar and nonplanar dielectric media. The figure of merit is to be low loss reflection of the EM wave from arbitrary directions and arbitrary polarizations over as broad a frequency range as possible. Careful attention should be paid to the possible deleterious effects of surface waves.

PHASE II: Deliver a user-friendly computer code which can be engaged to design useful devices, such as those mentioned above. The code should be capable of doing design trade-offs and otherwise exploring parameter spaces for optimality. Furthermore, the code must incorporate rigorous error control.

PHASE III DUAL USE APPLICATIONS: From a Phase III and dual use perspective, low loss optical fibers (cylindrical waveguides) for optical signal transmission would represent a major upgrade to the communications industry. Similarly the upgrade of lasers by way of low loss cavities would greatly benefit this ubiquitous device. Improved radar systems would be of value to the FAA as well as to those communities which monitor environmental compliance. In all these major dual-use cases, the present state-of-the-art is unresponsive to the particular needs of each user nor allows each commercial user to make optimal design choices. The Phase II code will fill this void.

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KEYWORDS: Photonic band Gap, Electromagnetic Wave Reflection, Improved Mirror

AF02T016 TITLE: Nano-Satellite Propulsion

TECHNOLOGY AREAS: Air Platforms

OBJECTIVE: Develop nanothrusters for precision thruster applications. These thrusters should exploit non-conventional physical processes that occur at the sub-micron scale.

DESCRIPTION: Nano-satellites (defined as those lighter than 1 kg) are gaining interest in the DOD community. The recent successes in nano-scale devices are leading to nanospacecrafts weighting as little as 1 kg. High-density digital electronics in smaller and smaller units translates into smaller and smaller space vehicles. However, no single factor constrains the design of space vehicles and the execution of their mission more than the state of art in propulsion technology. Nano-chemical propulsion can be used as a primary thrust system for orbit insertion, trajectory-control, and attitude control. Nano-electric propulsion may achieve some high delta-V maneuvers and attitude controls. Nano-thrusters based on sub-micron-scale and larger structures could produce tiny impulse bits for precision thruster applications and could exploit non-conventional physical processes that occur at the sub-micron scale. Batch operation enables the generation of higher thrust levels and impulse bits by parallel operation of many individual nano-thrusters. Batch-fabrication also enables inexpensive replication of entire thruster modules in lots of several hundred. The objectives are cluster-built pulsed solid/gas propulsion systems, self-consuming nanosatellites using nanoscale propulsion systems.

Scaling available thrusters to the required sizes presents several problems since physics in nanoscale do not apply at the non-continuum scales. For example, the breakdown voltage of nano-scale plasma is not known, nor is the gas flow behavior in nano-scale nozzles. These nozzles suffer from boundary-layer effects which become more dominant as the local Reynolds number decreases. The Maxwell equations may not be valid at these scales. New electromagnetic theory for nano scales may be necessary. More fundamental studies needs to be done in characterizing combustion and plasma dynamics in microscopic scales for future revolutionary nano-thrusters.

PHASE I: Design nanothrusters from the first principles. Research will focus on structurally integrated propellants, nano-scale combustion dynamics; understand and model micronozzles, micro-combustion, and heat-addition, sublimation, understand micro-plasma dynamics, identify scaling laws and model Hall, Field Emission, Colloid, pulsed plasma, ion and free molecule thrusters, study propellant feed systems at microscales, develop stable and reliable MEMS scale pressure and mass flow rate measurement techniques, study existing and new exotic propellants and their compatibility with silicon oxides.

PHASE II: Develop and test prototype of nano-thruster, and test feasibility of proposed nano-thrusters, compare with the models developed at the Phase I.

PHASE III DUAL USE APPLICATIONS: Advanced Propulsion Concepts, such as Electric, Pulsed Detonation, Electromagnetic, Beamed-Energy based propulsion offer new horizons for military applications at air, land, and sea. The development of low-cost, single-function nano and microsatellites offer new horizons for military and commercial applications, when they operate cooperatively either in clusters or in constellations. Nano and microsatellites offer the promise of lower cost, lower risk, and faster time to operation in space than the earlier generation of satellites. The cluster operates cooperatively to perform a function, in a sense as a "virtual" satellite.

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KEYWORDS: Space Propulsion, Nanosatellites

AF02T017 TITLE: Nanophotonics

TECHNOLOGY AREAS: Sensors, Electronics, and Battlespace Environment

OBJECTIVE: The object of the program is the growth and fabrication of submicron dimensioned photonic heterostructure devices with high dimensional and morphological control in order to enable the monolithic integration of microelectronic and photonic circuits.

DESCRIPTION: During the past several years, an exciting new class of nano-structured materials has emerged whose basic goal is to control the properties of electromagnetic waves (photons). Nanophotonics utilizes high-refractiveindex-contrast heterostructures that confine or manipulate light, e.g. waveguides, modulators, lasers, grating-based filters, ring resonators, couplers and photonic crystals. New physical phenomena wait to be discovered in this nanophotonic regime. As integrated electronic circuits approach the end of their roadmap, new nanophotonic phenomena and architectures represent a door of opportunity to the next dominant technology.

Recently exciting results have been achieved in nanostructure materials. These include strong photon-atom interaction in condensed matter, huge enhancement of light from Er:Si microcavity, submicron sized splitters and waveguides with very low loss, and waveguide-integrated, direct growth Ge on Si detectors with responsivities equivalent to InGaAs. A waveguide-integrated resonator built on a 1D photonic crystal design now holds the record for modal confinement (for 1.55 micrometer) at 0.055 micrometer3. Photonic crystals are periodic composites of macroscopic dielectric and/or metallic media and are designed to possess a complete (or omnidirectional) photonic band gap, i.e. a range of frequencies for which photons are forbidden to travel within the crystal for any direction of propagation. The presence of such an omnidirectional gap provides a new mechanism for unprecedented control of the confinement and propagation of light at very small dimensions, thereby enabling the design and integration of a large number and variety of optical nanodevices on a single chip. Because these devices depend on the coherent interference of light waves, the dimensional control and fidelity of structures must be better than ~1% of the optical wavelength in the medium.

PHASE I: Clearly demonstrate the feasibility of optical nanodevices for single chip implementation through confinement or manipulation of light in waveguides, modulators, lasers, grating-based filters, ring resonators, couplers and/or photonic crystals. Of specific interest is optical switching and light emission. Performance parameters need to be identified and the relevance to advanced optical networks, optical interconnects, and wavelength division multiplexing needs to be addressed. Limited work may be included associated with the lithography, patterning, and processing of photonic crystals.

PHASE II: Build upon Phase 1 work and demonstration of system components and implementation of a prototype. Perform appropriate analysis and modeling, grow the material or structure, fabricate the device and test its performance. Address the issues of integration (especially 3D), photonic bandgap (PBG) components on a chip, and the potential for a PBG photonic sensor.

PHASE III DUAL USE APPLICATIONS: This work is expected to enable the fabrication and design of monolithically integrated nano-heterostructures, leading to highly functional OE circuits. Applications of the nanophotonic elements in the field of quiet communications, enhanced responsivity OE transduction, photovoltaic energy conversion, remote smart sensors, parallel computing, optical logic, energy storage, and special coatings will result.

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KEYWORDS: nano-structured materials, nanostructures, photonic crystal, photonic bandgap, nanophotonics, optical nanodevices, integration, waveguides, optical switching, modulators, lasers, wavelength division multiplexing, WDM, PBG